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The Colour of Risk:
An Exploration of the IPCC's "Burning Embers" Diagram*,†

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This article tracks the historical emergence of a new visual convention in the representation of the risks associated with climate change. The "reasons for concern" or "burning embers" diagram has become a prominent visual element of the climate change debate. By drawing on a number of cultural resources, the image has gained a level of discursive power which has resulted both in material mobility and epistemic transformation as the diagram itself has become a tool for a variety of actors to reason with. The case brings to light a number of challenges associated with attempts to know and visualize abstract concepts such as risk and danger, including the social organisation of knowledge production and the role of expert judgment in contexts where science is asked to retreat from normativity.

I. Seeing climate change

How can climate change be visualized? The anthropogenic modification of the atmosphere's radiative properties through the emission of greenhouse gases and aerosols is an almost impossibly intangible, abstract, and remote phenomenon, distant in both space and time in many people's perceptions (O'Neill and Nicholson-Cole 2009). While the human-caused depletion of the planet's protective ozone layer became manifest in the figuratively visible "ozone hole" over the Antarctic, the complex causation and uncertain present and future impacts of climate change have generated "a mess of competing

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visual narratives characterized by suggestive shapes drawn by the plotted lines of story-laden graphs" (Hamblyn and Callanan 2009, 43). The notion that graphical representations of climate change are "story-laden" is not to undermine their relationship to physical realities. Rather it points both to the social processes of their construction and to their appropriation of culturally-embedded representational conventions in the ongoing struggle to render climate change "meaningful" (Schneider 2011; Doyle 2011). While graphic data representations have proven to be useful heuristics for coming to terms with the complex dynamics of the atmosphere, photographs have often been employed to visualize the possible impacts of climate change. Common tropes of stranded polar bears, flash flooding and parched soil can be found accompanying media coverage of climate change (Doyle 2007; Manzo 2010). Such discursive coupling is suggestive of direct causal relationships between climate change and the pictured impacts, even as the scientific debate over the attribution and prediction of extreme weather events appears irresolvable with any certainty (IPCC 2011).

It is into this representational milieu that the Intergovernmental Panel on Climate Change (IPCC) introduced the so-called "burning embers" diagram in 2001 (Figure 1). The diagram seeks to summarise a number of "reasons for concern" linked to the prospect of rising global temperatures. The left hand side of the figure, which appeared in the Working Group II *Summary for Policymakers* (2001), shows projections of global mean temperature (GMT) change up to 2100 based on various emissions scenarios and the results of numerous climate simulations. It is suggested that GMT could rise by up to 6°C by 2100. The right hand side of the figure schematically represents the level of danger associated with these rises in mean temperature above 1990 levels for five categories of concern. The change in colour from white to yellow to red is taken to denote risks of increasing magnitude, severity or geographic spread, and it is this colour palette which gave rise to the moniker "burning embers" among the diagram's creators.[1]

II. The colour of risk

In its original form in Chapter 19 of Working Group II's contribution to the IPCC's Third Assessment Report (TAR), the diagram appeared in greyscale (as did all diagrams in the main body of the report) and laid-out horizontally. This

[1] The following discussion is based on interviews with 11 scientists who were involved with the development of the diagram between 1999 and 2009. The disciplinary backgrounds and interests of the scientists varied between climate modelling, climate impacts analysis, economics and ecology. The interviews were conducted between May and December 2011. Interview data was supplemented by textual analysis of the publications in which the diagram appeared or was discussed.

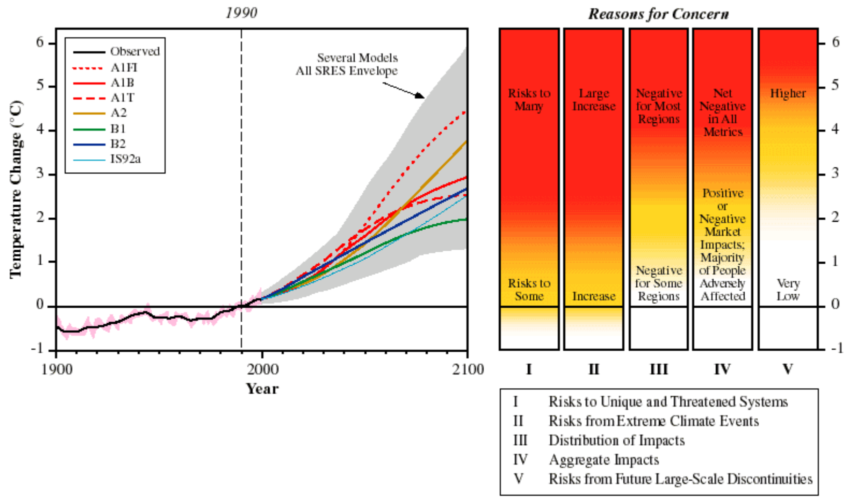

Figure 1. IPCC 2001. Projected temperature changes under different emissions scenarios (left) and "reasons for concern" or "burning embers" (right).

original version of the diagram was based on months of work by individuals on the writing team, who assessed the literature on climate change impacts across the five "reasons for concern." This categorization of impacts was a result of earlier deliberations within the team which led to a desire to synthesize the textual information in the form of an accessible visualization. The diagrammatic format demanded that projected impacts be tied to specific temperature points and, as literature on climate change impacts was sparse at the time, the authors had to exercise personal judgment in determining where the colour shifts should take place.

This kind of risk visualization was not without precedent in the climate change literature. A decade earlier, Rijsberman and Swart (1990) and Vellinga and Swart (1991) presented the "traffic light" system of risk visualization and management (Figure 2). This employed three discrete blocks of colour—green, amber and red—to represent increasing rates of GMT and sea level rise and their risk corollaries (although again, printing practices reduced the colours to shades of grey). The aim of this visual device was to propose targets for temperature stabilisation. The transition from green to amber occurs with a 1℃ rise above pre-industrial levels, while the red light is associated with a 2℃ rise. The authors argue that the:

> goal of our effort must be, therefore, to go for the green light, and in any case, to fully avoid the red light. To avoid the red light means that we want to limit the GMT rise to well below 2℃ with respect to the pre-industrial level and that we want to limit the sea level rise to well below 50cms. (Vellinga and Swart 1991, 131)

This was the first time that maximum temperature change was used as a means of normatively framing a target-based approach to global climate policy (cf. Nordhaus 1977), and was a key moment in the establishment of the 2°C target as an anchoring device for scientific and political discussions of climate change (Randalls 2010).

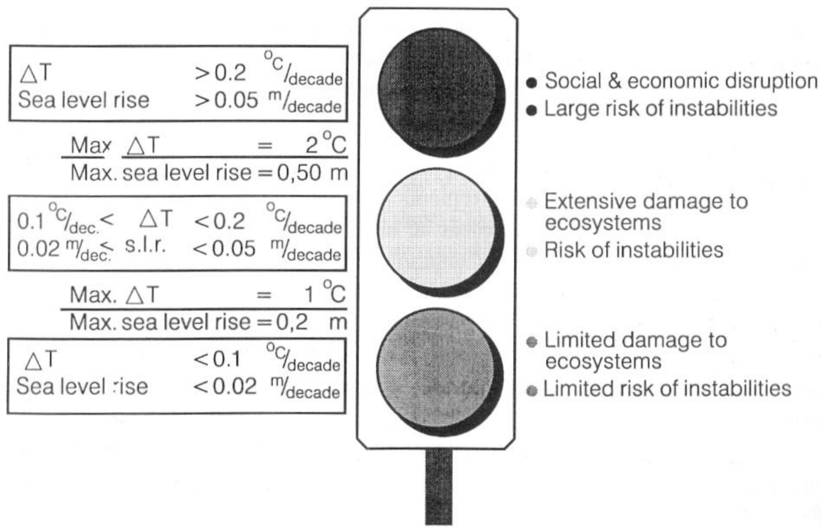

Figure 2. Vellinga and Swart 1991. The "traffic light" approach to risk management.

Diagrams such as these combine expert judgments of observational evidence, future predictions, and normative judgments of risk. Unlike quantitative scientific visualizations which commonly aim at an ideal of unmediated representation or an "analogue" of physical reality (Daston and Galison 2007; Barthes 1977), here the viewer's interpretation is guided explicitly by the design choices and their attendant normative elements. The desirability of the bottom scenario is prefigured in the green traffic light; likewise the undesirability in the red. The normative content of the temperature and sea level rise scenarios is not left to the viewer's interpretation. The familiarity of the traffic light—and the images it conjures of momentum continued, tempered or abated—directs interpretation towards this seductively linear notion of pathways and targets. This notion has since been criticised for its reductiveness and its tendency to distract from the politically and ethically complex task of reducing emissions (Randalls 2010). According to this construction, it is science which is almost literally directing the traffic and showing the way.

The "traffic lights" had a direct influence on the development of the "burning embers" diagram. During the early stages of the writing team's deliberations, a diagram was proposed which employed a similar transition from green to red along each "line of evidence" column, as they were known before "reasons for concern." However, this palette was dismissed, as it was thought that the green element indicated an absence of risk or even safety for some levels of climate change—something which the authors took as being contrary both to their own understandings of the risks and to the message they sought to convey (interview, December 1, 2011). The neutrality of white was thus employed as the baseline on which to build the negativity of red. The ordering of the columns was also decided based on a combination of epistemic and aesthetic considerations. Neither fundamentally scientific nor axiological reasons are given for the ordering. Rather, this composition was deemed the most visually appealing, producing an upward-trending diagonal in the emergence of yellow, from column two to column five (interview, November 4, 2011). It is a graphical design choice, but one which provides visual and rhetorical echoes of the rising forms of many high-profile climate visualizations, from Michael Mann's famously controversial "hockey stick" temperature chart on the pages of IPCC reports to Al Gore's dramatically exponential CO2 concentrations in *An Inconvenient Truth* (Hamblyn 2009; Schneider 2011).

As in the "traffic lights," a sense of danger is pre-figured in the "burning embers" colour palette. The colour red has been graphically associated with high temperatures since the nineteenth century (Schneider 2011), but its connotative associations with danger, fear, violence, and passion have a much longer and more engrained lineage in Western cultures (Gage 1999). The embeddedness of this scientific diagram within these political discourses and cultural conventions is the source of its meaning. It is also the locus from which it has achieved mobility as an actant within the networks which tie together science, politics, culture and ethics, further blurring their already permeable boundaries while undergoing a number of epistemic transformations.

III. Epistemic transformations

The "burning embers" diagram achieved a great deal of visibility following its publication in 2001 and has arguably become one of a few iconic scientific visualizations giving illustration to the climate change debate (Liverman 2009).[2] In a particularly interesting use of the "burning embers" diagram, Mastrandrea and Schneider (2004) use the image as a foundation for a probabilistic assessment of the chances of avoiding "dangerous" climate change under certain

[2] See, e.g., West Coast Climate Equity, Present targets for CO2 emission cuts will not prevent a 4C global temperature rise, Last modified July 11, 2010, westcoastclimateequity.org/2010/07/07/present-targets-for-co2-emission-cuts-will-not-prevent-a-4c-global-temperature-rise/ ; Greenpeace Australia Pacific, Treading on burning embers, Last modified September 29, 2009, www.greenpeace.org.au/blog/?p=875; Climate Change Food Security, Policy making, Last accessed July 27, 2012, www.climatechange-foodsecurity.org/policy.html; UNEP, *Climate Change Science Compendium 2009*, (Nairobi, 2009); and G. Yohe, 'Reasons for concern' (about climate change) in the United States, *Climatic Change* 99(1-2) (March 2010): 295-302.

policy initiatives. A cumulative density function of the threshold of dangerous anthropogenic interference (DAI) is constructed by placing a data point at the level at which each column turns red (see Figure 3). The authors justify this strategy by stating that each column represents the judgment of "dozens of IPCC lead authors' examination of climate impacts literature," and therefore that the red zones represent "a consensus estimate of DAI" (Mastrandrea and Schneider 2004, 572). The "dangerous" temperature thresholds are then used to explore the sensitivity of projections of DAI to three model parameters[3] enabling the authors to claim that the probability of DAI can be reduced from around 45 percent to near zero by increasing "policy controls."

Mastrandrea and Schneider's analysis transforms the burning embers' blurred, uncertain judgments of future climate impacts into a quantitative profile of risk and danger as the global temperature moves up the scale from its late twentieth century baseline. The temperature thresholds for radical changes in social and natural systems, drawn initially from climate impacts studies and then amalgamated and obscured in colour, re-emerge as new points: average thresholds, calculated not from the collected-together numbers of the impacts literature, but from the shifting colours of their graphical approximation. Point becomes blur, blur becomes point.

This epistemic transformation illustrates both the challenges of visualizing risk, and the power of consensus in addressing complex environmental issues. The visualization of risk involves not only an attempt to capture and represent physical processes and phenomena. It also represents their interaction with social systems, certain interpretations of the meaning of that interaction, and the social and political capacity to respond to an emerging danger, should it be deemed to be of sufficient magnitude and urgency. The calculation of risk is thus often a task bestowed upon those with the necessary technical expertise to comprehend the complex, multi-faceted nature of anthropogenically "manufactured risks" (Giddens 1999). The concept of "risk" itself "has come to stand as one of the focal points of feelings of fear, anxiety and uncertainty" pertaining to the future (Lupton 1999, 12). Its calculation must therefore involve grappling with the epistemological, ontological, and ethical uncertainties which are constitutive of any effort to project what is known into the future, and then to draw on such projections to reflect on how society should be directed in the present (Beck 1992; Felt and Wynne 2007). Such knowledge will always be incomplete and partial—it will vary between experts, social constituencies, and cultures (Lupton 1999). The social organisation of knowledge therefore becomes a key source of epistemic authority, with assessment, synthesis, and consensus

[3] The model parameters investigated are the estimated climate sensitivity to a doubling of CO2 concentrations, projected economic damages, and the discount rate, i.e. the way present costs and benefits are weighed-up against future costs and benefits.

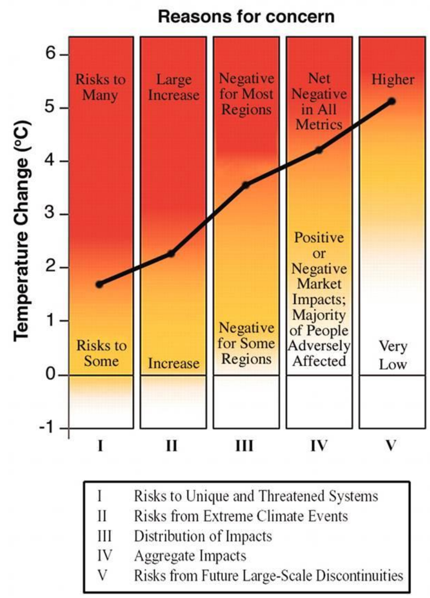

Figure 3. Schneider and Mastrandrea 2005. Adaptation of the "burning embers" diagram. The thresholds of dangerous climate change are marked by the black points and connecting line, positioned where each column begins turning red.

being central strategies for the application of scientific expertise to questions of societal risk.

The IPCC is mandated to produce consensus. Despite the pursuit of consensus being arguably "a source of both strength and vulnerability for the IPCC," the notion of "consensual science" carries great discursive power in climate change debates (Hulme and Mahony 2010, 711). For many analysts (e.g. Edwards and Schneider 1997), the attainment of consensus has been politically instrumental in convincing the world of the need to act on climate change and thus for the advancement of international climate policy.[4] Consensus can also be said to be generative of community identities, especially those articulated around epistemic norms and values (Horst and Irwin 2010; Haas 1992). Although gaining authority through its representation of a form of consensus, the "burning embers" diagram has not always attracted a broader consensus beyond the epistemic community which innovated and developed the diagram.

The IPCC chapter which gave rise to the original "burning embers" was

[4] See also D.H. Guston, On consensus and voting in science: From Asilomar to the National Toxicology Program, in *The New Political Sociology of Science: Institutions Networks, and Power*, ed. Scott Frickel and Kelly Moore, 373-404, (Madison, WI: University of Wisconsin Press, 2006); and H. Graßl, A discernible human influence on the global climate - How the IPCC affected climate Politics, *GAIA - Ecological Perspectives for Science and Society* 18(3) (September 2009): 255-56.

re-mandated for the Fourth Assessment Report (AR4), albeit with many new authors. Although the "key vulnerabilities" (Schneider et al. 2007) and "reasons for concern" (IPCC 2007) analytical frameworks persisted and were updated textually (the latter in the IPCC's Synthesis Report), the "burning embers" diagram was absent in the final report. In interviews, authors of the chapter reported a reluctance to wholly import the analytical framings from the TAR, as the AR4 team was required to assess a rapidly evolving and expanding literature. However, towards the end of the writing process, it was decided amongst some authors that an update to the "burning embers" diagram would be appropriate. An updated version of the burning embers diagram was thus presented for inclusion at the Working Group II plenary session. However, the lack of a version of the diagram in the underlying chapter later opened space for procedural objections from government delegations, with the late Steve Schneider, Coordinating Lead Author of the chapter, reporting that "four fossil fuel dependent countries accepted the text but refused the figure," seemingly on the grounds that it was "too much of a judgment" (quoted in Revkin 2009). A combination of these governmental protestations, the tight timescales of IPCC drafting processes, and certain objections to this particular analytical framing within the Working Group II hierarchy conspired to see the updated embers excluded from the AR4. The updated diagram was eventually published by a group largely consisting of chapter authors in the *Proceedings of the National Academy of Sciences* (Smith et al. 2009; see Figure 4).

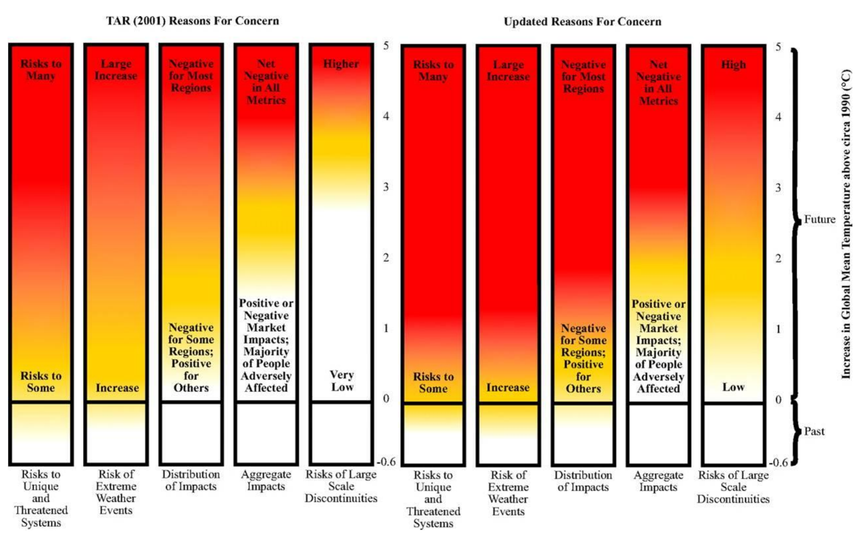

Figure 4. Smith et al. 2009. Updated "Reasons for Concern."

Schneider's claim that the diagram represented too much of a "judgment" for some parties emphasises the challenge of negotiating the boundary between description and prescription. The preservation of this boundary is inscribed both in the IPCC's mandate and in the norms of much contemporary scientific practice (Shapin 2008; Walsh 2009). The shift from the left- to the right-hand side of Figure 4, with the visually striking descent of the red, does not portray a change in the ontological status of the risks between 2001 and 2009, but rather maps the changing content of scientific understandings and judgments. The diagram seeks to represent the consensual amalgamation of these judgments, and the authors openly relate the potential for subjectivity in this mode of knowledge production and synthesis (Smith et al. 2009). However, the cognitive and social-epistemological processes which are generative of such judgments are largely indiscernible to the outside observer.

IV. An icon of late modernity

The "burning embers" diagram is a collage of space and time (Schneider 2011) with GMT standing in for an indeterminate temporality, while the global is collapsed into the limited dimensionality of graphematic space. This level of abstraction has been a source of criticism. For example, Liverman (2009) argues that the diagram elides the complex geographies of climate change impacts in its effort to present a globalized conceptual space. The dominant "global gaze" of climate science is not an epistemological inevitability, but is rather the result of the complex intertwining of science and politics (e.g. Miller 2004; Oels 2005). For instance, since its inception the "reasons for concern" framework has sought to address a principle enshrined in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC)—the avoidance of "dangerous anthropogenic interference (DAI) with the climate system" (UN 1992).

While attempting to avoid overt policy prescriptiveness, the "reasons for concern" framework has sought to provide illustrative guidance on what might be considered a dangerous level of global mean temperature rise. However, the framework seeks to address only the dangers associated with anthropogenic climate change, rather than those associated with natural climate variability. For example, it is suggested in all versions of the diagram that at some point below 1990 temperature levels that the risks associated with extreme weather events were "virtually" zero or "neutral." Of course extreme weather happened long before 1990, but the "reasons for concern" framework seeks to address only that which may be attributable to human actions. This inverse purification of the "human" from the "natural" (cf. Latour 1993) is a function of the diagram's direct engagement with the policy question of "dangerous anthropogenic interference." It thus functions as a heuristic for the dangers associated with an imagined, human-made climate of linear trends and direct causalities, rather than a complex, hybrid climate where cycles, trends and social trajectories interact chaotically in perhaps unknowable ways.[5]

[5] For an example of the political implications of this purification, see M. Hulme, S.J. O'Neill and

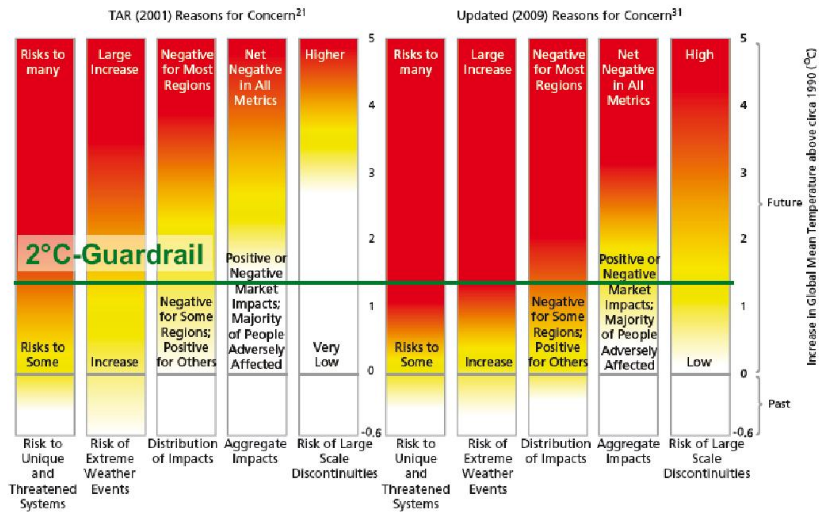

Figure 5. Richardson et al. 2009. The "burning embers" as they appear in Richardson et al.'s synthesis of an international scientific conference which took place in the run-up to the Copenhagen climate negotiations of December 2009. The positioning of the "2°C guardrail" at around 1.4°C represents the discrepancy between pre-industrial and 1990 temperature baselines, the latter being preferred in IPCC assessments.

As an "epistemic thing" (Rheinberger 1997), the "burning embers" diagram does not simply fulfil a representational role, but rather functions as an object *within* a system of enquiry (see for example Figures 3 and 5). However, instead of Rheinberger's tightly bounded and regulated laboratory spaces, the "burning embers" diagram functions in a much wider arena. There the conditions "of the possibility of things becoming epistemic things" (Rheinberger 1998, 297) are as much political and discursive as they are determined by the materiality of scientific enquiry (Jasanoff 2004; Foucault 2007). The "burning embers" diagram is thus a hybrid form: representational and heuristic, forensic and epideictic;[6] the outcome of an institutionalized, yet indeterminate, encounter between object and subject. This hybridity, while posing challenges to certain scientific norms, is emblematic of the complex interweaving of competing epistemologies with the challenges of intractable uncertainty which characterises late-modern "risk societies" (Beck 1992).

For theorists such as Ulrich Beck (1992) and Anthony Giddens (1991), industrialized societies are experiencing conditions of late modernity. This represents a continuation or radicalisation of the institutional, economic, and cultural changes wrought by modernisation to a point where socioeconomic

S. Dessai, Is weather event attribution necessary for adaptation funding? *Science* 334(6057) (November 11 2011): 764-65.

6 See Walsh (2009) for a discussion of climatological imagery through the lens of Aristotelian rhetoric.

processes generate hazards of a scale which require modernity to reflect on itself and to challenge its assumptions of progress and interminable growth. Late modern societies are preoccupied with the future. This preoccupation most often takes the form of the calculation of hazard probabilities and of the social acceptability of risks in order that they may be managed or "controlled." However, late modernity is also characterized by risks of a sort which belie easy calculation, spatio-temporal delineation or straightforward democratic appraisal. The blurring colours of the "burning embers" exemplify this paradoxical societal relationship with risk as an object of scientific enquiry and political concern.

It is in this societal milieu that the "burning embers" diagram may be said to function much like an expressionist painting. During the early twentieth century the expressionist movement pursued an artistic style which prioritised subjective experience, meaning and emotion in a direct rebuttal to realist and naturalist representational paradigms (Willett 1970). Likewise, the "burning embers" diagram seeks not to figuratively represent a phenomenon (the changing climate), but rather its intangible effects.[7] These effects, be they heightened levels of danger or risk, are quickly translated into affect through the use of literary and visual conventions such as the emotionally charged colour palette. The expressionist movement arose in Germany in part in response to conditions of social crisis and upheaval (Whitford 1970). The "burning embers" diagram feeds certain anxieties about the future; we can sense ourselves walking powerlessly into the red heat, a fate made all the more inevitable as the red zone creeps towards the colourless safety of the baseline. In the case of this diagram, scientific visualization is not the disinterested gaze of technical apparatus. Rather, it is a suite of social-epistemic practices situated firmly within a set of cultural discourses in the uncertain, reflexive time-space of late modernity. The semiotic, epistemic and social elements of such constructions cannot be understood in isolation, or even analytically delineated. Here they are mutually constitutive, combining and re-combining in a particular graphematic space to produce a mobile and evolving visual convention.

V. Conclusion

This article began by posing the question of how climate change can be visualized. The example of the "burning embers" diagram itself raises the question of whether the exercise of subjective expert reasoning is compatible with the demands of diagrammatic reasoning. It has been argued that the notion of risk is highly complex in epistemic and normative terms, especially when

[7] Coincidentally, one of the most famous examples of expressionist architecture—Erich Mendelsohn's Einstein *Tower in Potsdam*—lies just a few yards from the meeting room where the burning embers diagram was first conceived by IPCC authors.

considered in the context of climate change (Hulme 2009). A perfectly "objective" assessment of the risks posed by a changing climate would be impossible, and the authors of the "burning embers" diagram are right to acknowledge the inevitable subjectivity of such judgments. As a *heuristic* tool, the diagram functions well in its suggestion of when (or, more precisely, at what temperature) danger might be encountered under a changing climate, as evidenced by the variety of uses to which the diagram has been put. As *representation*, the diagram is weakened by the opacity of what exactly is being represented. In the translation from assessment of scientific literature to diagrammatic form, a wide body of scientific knowledge is condensed into a suggestive array of colour with the somewhat inevitable loss of what Latour (1999) terms "reference"—the traces, marks and symbols which tie together mind and world.

Despite the widespread rhetorical policing of the boundary between description and prescription, this case makes clear that the communication of climate change through visualization relies not only on translation, but also on what Walsh (2009) terms a "performance of continuity" across the is/ought divide. Highlighting the normative underpinnings of this continuity is perhaps incompatible with the demands of diagrammatic reasoning and the limitations of graphematic space. Our knowledge of the complexity of the climate system is growing and different normative stances on climate change are proliferating, for example in judgements about what might constitute a "key vulnerability." In this context, scientists working at the science-policy interface may need to find new, creative ways of communicating their findings. Recognising and communicating epistemic uncertainty and normative diversity will be central to the success of such efforts.

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